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Measuring coordination of epilepsy care: A mixed methods evaluation of social network analysis versus relational coordination

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ABSTRACT

Objectives: Coordination of multidisciplinary care is critical to address the complex needs of people with neurological disorders; however, quality improvement and research tools to measure coordination of neurological care are not well-developed. This study explored and compared the value of social network analysis (SNA) and relational coordination (RC) in measuring coordination of care in a neurology setting. The Department of Veterans Affairs Healthcare System (VA) established an Epilepsy Centers of Excellence (ECOE) hub and spoke model of care, which provides a setting to measure coordination of care across networks of providers.
Methods: In a parallel mixed methods approach, we compared coordination of care of VA providers who formally engage the ECOE system to VA providers outside the ECOE system using SNA and RC. Coordination of care scores were compiled from provider teams across 66 VA facilities, and key informant interviews of 80 epilepsy care team members were conducted concurrently to describe the quality of epilepsy care coordinating in the VA healthcare system.
Results: On average, members of healthcare teams affiliated with the ECOE program rated quality of communication and respect higher than non-ECOE physicians. Connectivity between neurologist and primary care providers as well as between neurologists and mental health providers were higher within ECOE hub facilities compared to spoke referring facilities. Key informant interviews reported the important role of formal and informal programming, social support and social capital, and social influence on epilepsy care networks.
Conclusion: For quality improvement and research purposes, SNA and RC can be used to measure coordination of neurological care; RC provides a detailed assessment of the quality of communication within and across healthcare teams but is difficult to administer and analyze; SNA provides large scale coordination of care maps and metrics to compare across large healthcare systems. The two measures provide complimentary coordination of care data at a local as well as population level. Interviews describe the mechanisms of developing and sustaining health professional networks that are not captured in either SNA or RC measures.

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1. Background

Improving care coordination among clinicians is a major strategic goal in reforming the healthcare system [1]. Effective coordination between primary care and specialty care practices have been highlighted by the American College of Physicians as essential to patient-centered care [2]. The Institute of Medicine has emphasized the importance of coordination of care, including "comanagement for patients with comorbid conditions whose care may cross specialty boundaries".

Despite calls for improved coordination of care over the last two decades, research examining healthcare provider interdependencies and communication, especially as related to neurological subspecialty care, remains limited.

Social network analysis (SNA) and relational coordination (RC) are two approaches for examining coordination of care between providers. Social network analysis methods have been validated to specifically quantify physician-to-physician patient sharing patterns; SNA methods also reflect the level of information-sharing across physicians [3,4]. In

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contrast, RC is a mutually reinforcing process of communicating and relating for the purpose of task integration whereby work is coordinated through relationships of shared goals, shared knowledge, and mutual respect [5]. Specifically, RC measures quality of communication, characterized as frequent, timely, accurate, productive, and problem-solving. It also measures the level of shared goals, shared knowledge, and mutual respect [6], across all members of the healthcare team (not only physicians). Relational coordination provides a global measure of interpersonal coordination as well as in-depth information of the functional roles and attitudes of each health professional.

Social network analysis measures physician connectivity by extracting administrative data from electronic health records (EHR) [4,7,8]. Connectivity is defined by the number of shared patients between physicians, and the more patients shared, the more likely the connected physicians seek "informal clinical advice" from each other [4]. Greater numbers of shared patients are theorized to offer more opportunities for information exchanges between providers, which in turn may influence provider behavior, resulting in higher quality of care [8].

Unlike SNA, RC requires original data to be collected by healthcare providers; these data cannot be extracted from the EHR [9]. The RC survey collects detailed information about communication and functional roles in a 360-degree approach (every healthcare provider and staff evaluates the communication and functionality of everyone else in the team); RC has been linked to information sharing as well as efficiency and quality of care [10].

The purpose of this study is to demonstrate the value and limitations of SNA and RC for measuring coordination of care as well as for learning from healthcare team members' on-the-ground experience with epilepsy care coordination. We demonstrate the use of SNA to capture the network of provider relationships in a large national healthcare system and to evaluate the nature of communication among the same physicians as well as their respective multidisciplinary team. We use RC to investigate the individual relationships between members of a healthcare team within an organizational unit. We draw from key informant interviews to explore individuals' experiences with care coordination and develop new understanding of *how* and *why* RC and SNA are, or are not, similar and how each method can be used most effectively.

2. Methods

2.1. Design

A parallel mixed methods design was employed to explore similarities and differences between two approaches for assessing epilepsy care coordination. We identified providers who had at least one clinical encounter with patients with epilepsy, and calculated the number of shared patients between providers in the SNA using Veterans Health Administration (VA) administrative data. Data collection for surveys and interviews assessing RC in a purposive sample, which focuses on key stakeholders involved in care processes [11]. As opposed to randomly surveying or interviewing healthcare providers, we specifically selected those in epilepsy care within the VA healthcare system. Surveys and interviews of VA epilepsy providers and nonprovider team members were conducted in parallel to the SNA data collection. The RC and SNA data were analyzed independently to determine the extent that concepts relevant to each framework emerged. Furthermore, in-depth interviews were conducted to better ascertain factors that influence coordination of epilepsy care and to assess how these factors are captured by RC and SNA. Additional details of the study are published elsewhere [12].

2.2. Setting, recruitment, and data collection

We conducted our study in the VA Epilepsy Centers of Excellence (ECOE). This national program provides comprehensive care for Veterans with epilepsy by coordinating care between "hub" ECOE facilities and "spoke" referring facilities. Primary care providers as well as neurologists refer Veterans to epilepsy specialists located at ECOE facilities for seizure work-up and/or management. We developed a participant pool of 750 healthcare professionals involved in epilepsy care by compiling national lists of neurologists, ECOE clinicians, staff, and workgroups, email distribution lists, and physicians listed in the 2012 Federal Practitioner Directory. We employed Dillman's tailored design method to recruit participants [13]. An invitation to participate in the study was emailed to the list and followed by subsequent emails with a link to an online survey hosted by Research Electronic Data Capture (REDCap®). Survey data were collected during a 2-month period from February–March, 2013. Interviews were conducted from February–May, 2013. Social network analysis mapping was conducted for encounters complete in 2013.

2.3. Social network analysis

Data for SNA were extracted from the VA Corporate Data Warehouse on all Veterans with a diagnosis indicative of seizures (International Classification of Diseases, Ninth Revision [ICD-9] codes 345.X, 780.39) who are seen by neurologists and other health providers at 66 of the 152 VA medical centers that were sent surveys. Other providers included primary care, internal medicine, medical subspecialties, physiatry, surgical subspecialties, and mental health. Neurologists and other providers had to complete at least one inpatient or outpatient encounter with a shared patient with epilepsy, respectively, in fiscal year 2013 to be included. Patient encounters were aggregated to identify all physicians who had either seen a given patient or been involved in a consultation. Connections (edges) between providers were defined by the number of shared patients between two respective providers; shared patients form edges between providers (Fig. 1). Among the common measures of how connected or influential a provider is in a defined network of providers are node degree (which may be adjusted by the size of a facility), betweenness centrality, and closeness centrality [14]. The *node degree* for each provider is calculated by summing the total number of edges of each provider. Node degree of each facility was calculated by summing node degrees for all providers at that facility. Adjusted node degree of neurologists was calculated by dividing the average degree within the facility by the total number of neurologists in a given facility. Betweenness centrality is the proportion of paths between two providers that go through a provider of interest; it measures how much a provider connects two other providers within the network. Closeness centrality is the sum of the shortest paths between any two providers within a network; it reflects how accessible a provider is to all other providers. Visualizations of VA facility networks are produced using Fuchterman Reigngold layout in Gephi 0.9 [15].

2.4. Relational coordination

The RC score is a composite of 7 dimensions measuring attributes believed to be important in coordinating interdependent work: communication frequency, accuracy, timeliness, and problem-solving vs. blaming communication; shared knowledge, shared goals, and mutual respect. Each dimension is scored by individual team members (range 1–5, with 5 being the most favorable score, and 4 and above considered as strong scores). We modified Gittell's 2009 survey to gauge RC across the nationwide network (i.e., system level) by asking participants to rate epilepsy care team members at their own site ('at your station'; hereafter, *intrafacility*) and at a site where their patients' care is also coordinated where the patient has been previously referred ('at another station'; hereafter, *interfacility*). Referrals made to providers at one's own facility are designated *intrafacility* while referrals made to another facility are designated *interfacility*.

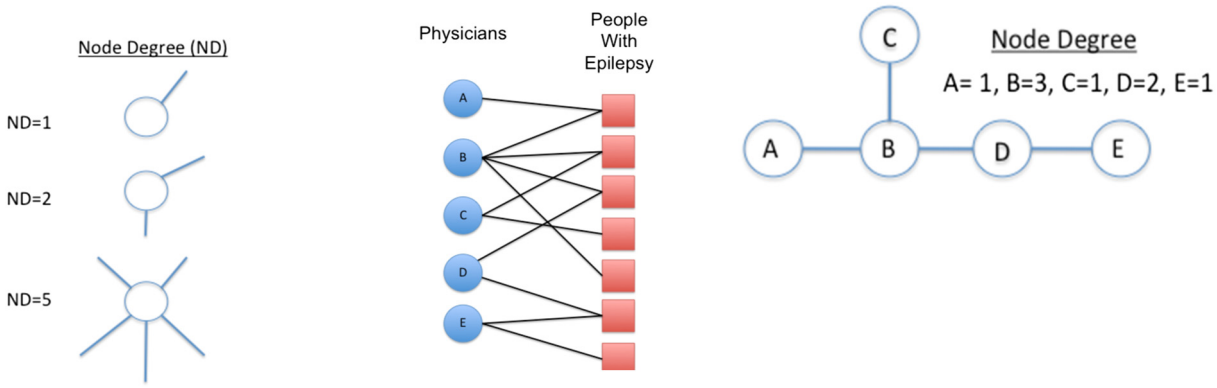

Fig. 1. Measuring physician networks using social network analysis. a) Each circle (node) represents one physician and each line represents a connection, as defined by number of shared patients, to another physician. For instance, with a node degree (ND) = 1, the physician shares a patient with one other physician. ND = 5 connotes the physician of interest shares at least one patient with five different physicians. b) SNA physician maps are created by linking shared patients to physicians. c) SNA maps of physician networks demonstrate how connections occur. Adapted from: Altalib HH, Fenton BT, Cheung KH, Pugh MJ, Bates J, Valente TW, Kerns RD, Brandt CA. Care coordination in epilepsy: Measuring neurologists' connectivity using social network analysis. Epilepsy & Behavior. 2017 Aug 1;73:31-5.

2.5. Qualitative analysis

We designed a 13-question semi-structured interview guide to explore concepts related to the restructuring of epilepsy care in the VA. Examples include, *"Can you describe the care journey of a patient with spells or seizures who is referred either for evaluation to your facility or to an Epilepsy Center of Excellence?"*; "*How satisfied are you with the referral process?"; "Can you tell me about your understanding of the Epilepsy Center of Excellence network and how your facility fits within it?"; "How has the care you provide and/or role you play changed over the past two to three years?"*

Key informant interviews of epilepsy care team members from facilities invited to participate in the surveys (i.e., epileptologists, neurologists, nurses, electroencephalograph [EEG] technicians, pharmacists, neuropsychologists, psychologists, and administrative officers [AO]) were conducted by one researcher (KM). A constant comparative method [16] was used and interviews continued until data saturation was reached where no new themes emerged. Interviews were digitally recorded, transcribed verbatim, and edited for clarity, consistency, and anonymity. All data were managed in NVivo qualitative data analysis software (QSR International Pty Ltd. Version 10, 2012).

Our analytical approach for this analysis was based on a directed content analysis methodology [17]. Coding was conducted in two phases. Deductive codes based on a literature review of social networks in healthcare were developed by the lead investigator, HA, a dual board-certified neurologist and psychiatrist. Two researchers (EB, an anthropologically trained research associate, and KM, a social psychologist) individually coded all transcripts and assessed agreement. Any discrepancies were resolved by HL, a healthcare organizational scientist. The final coded material was reviewed by the team, which included a health services researcher MJP, in a series of weekly meetings to discuss clarity, consistency, and accuracy of coding and emerging themes.

3. Results

The SNA and RC scores were analyzed in 66 facilities (15 ECOE hub facilities and 51 spoke facilities). Of the 750 requests for RC surveys, 203 initiated the survey, 38 were eliminated because they were incomplete or duplicated surveys with a completion rate of 165/750, or 22%.

For these analyses, we purposively sampled surveys from 57 providers including 39 general neurologists, 13 epilepsy specialists, and 5 nurse practitioners, physician assistants/associates, or clinical pharmacists. As the perceptions of clinical staff were deemed necessary for accurate assessment of patient coordination, facilities with surveys from only administrative personnel or EEG technicians were dropped from the analyses.

3.1. Social network results

Table 1 compares SNA metrics across all VA facilities nationally. Across VA facilities, neurologists were found to be higher on average node degree, betweenness, and closeness centrality measured followed by mental health professionals, then primary care. Furthermore, providers, across disciplines, had higher centrality measures in ECOE hubs compared to spoke referral facilities and nonaffiliated networks (Table 1).

However, in spite of the above general trends, facilities had a variety of network configurations. Fig. 2 demonstrates different configurations of coordination of care in five different VA facilities. In Fig. 2a, patients with epilepsy are shared evenly between neurologists. Blue nodes representing neurologists in Fig. 2b are relatively larger compared with the other nodes, indicating that they share markedly more patients with epilepsy compared to the other provider types. In the facility represented in Fig. 2c, one neurologist appears to coordinate the majority of epilepsy care relative to the other neurologists. In Fig. 2d, several of the internal medicine specialists (in yellow) are relatively larger and coordinate disproportionally more patients with epilepsy than other internists as well as primary care providers. In Fig. 2e, the psychiatrists appear to be more tightly connected (relatively closer to the center) compared to psychiatrists in other facilities.

3.2. Relational coordination

Table 2 presents descriptive analysis for relational coordination scores. Average RC scores ranged from 3.72 (interfacility neurology) to 3.98 (intrafacility overall), which is at the higher end of the RC scale; there were no individual scores under 2.43. In contrast, adjusted node degree had an extremely wide range, revealing low- and high-connected sites. The RC scores were higher among neurologists and epileptologists within ECOE affiliated facilities compared to those outside the ECOE system. Specifically, epileptologists outside ECOEs scored

Table 1
Relational coordination scores.

Relational coordination	N	*M*	*SD*	Range	Spearman correlation	*p*-Value
RC system level	41	3.79	0.52	2.43–4.63	0.356	0.022*
RC intrafacility	40	3.98	0.54	2.71–5.00	0.260	0.105
RC interfacility	37	3.69	0.50	2.43–4.57	0.247	0.140
RC neurology/system level	41	3.89	0.63	2.43–5.00	0.337	0.031*
RC neurology/intrafacility	39	3.96	0.59	2.71–5.00	0.313	0.052
RC neurology/interfacility	15	3.72	0.55	2.43–4.71	0.416	0.123

* p values of <0.05.

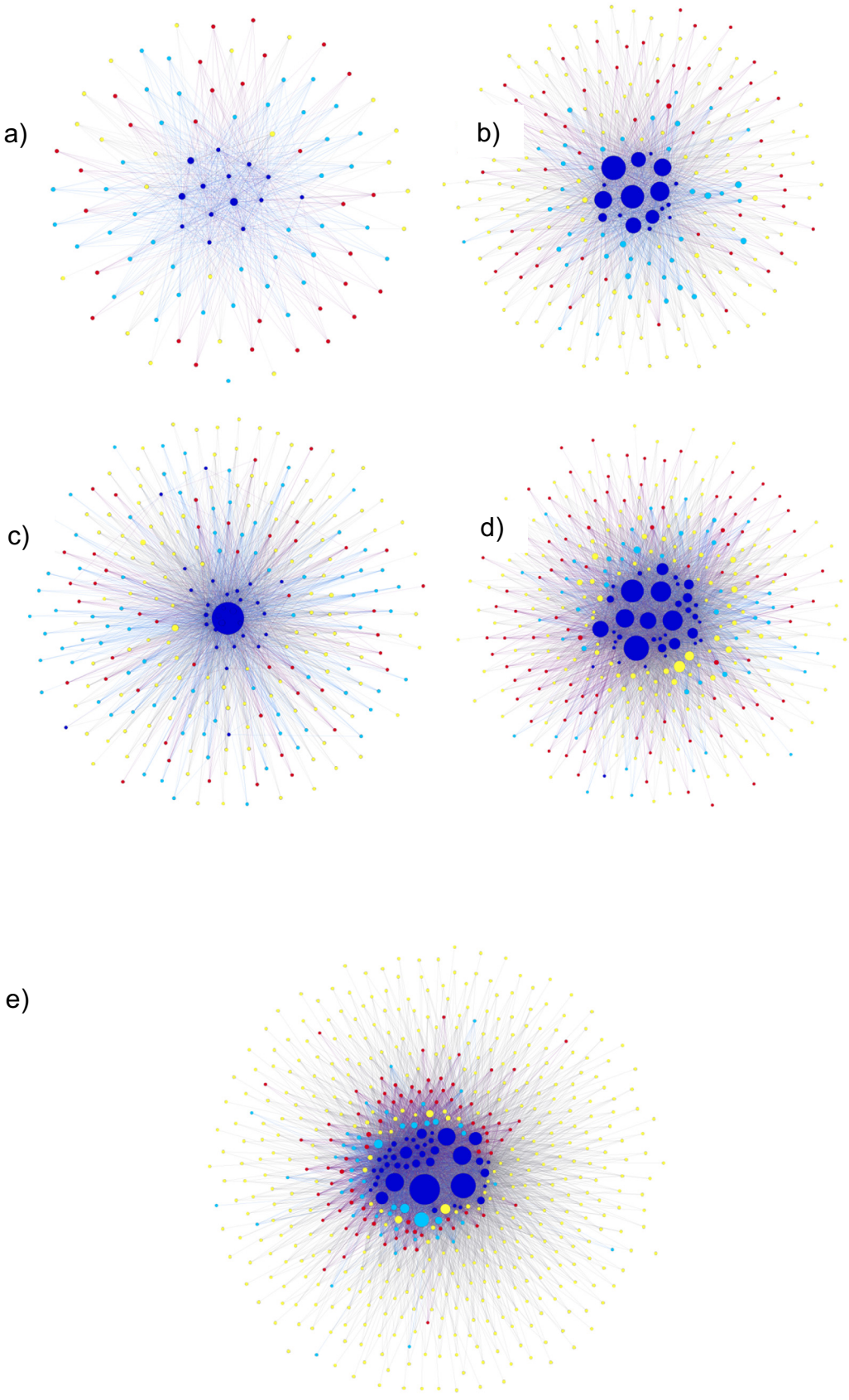

Fig. 2. Social network physician maps of five VA facilities. Nodes are color coded by physician specialty: blue, neurology; turquoise, internal medicine; yellow, primary care; and red, psychiatry.

Table 2
Social network analysis of epilepsy coordination of care in VA facilities nationwide.

Region	Provider	Min*	Max	Median	Average	Standard deviation
A Average Node Degree						
	All**	2.21	140.88	11.24	21.99	28.07
	IM	3.8	27.95	12.54	13.51	6.93
ECOE	NEURO	12.63	140.88	57.54	62.11	36.32
	PCP	2.21	22.31	7.97	10.04	6.38
	MH	2.43	16.08	6.82	7.33	3.29
	All	1	85	6.76	12.75	16.32
	IM	2.14	47.33	9.30	10.76	7.79
Non-ECOE	NEURO	7.5	85	43.32	42.92	21.79
	PCP	1	16.43	4.15	5.45	3.88
	MH	1	13.18	4.8	5.64	3.51
Region	Provider	Min	Max	Median	Average	Standard deviation
B Average Closeness						
	All	0.51	2.73	1.43	1.44	0.36
	IM	0.93	2.73	1.36	1.46	0.41
ECOE	NEURO	1.1	1.72	1.33	1.34	0.19
	PCP	0.51	1.94	1.5	1.38	0.43
	MH	0.92	2.17	1.60	1.56	0.35
	All	0	1.92	1.25	1.21	0.37
	IM	0.69	1.87	1.28	1.22	0.34
Non-ECOE	NEURO	0.76	1.84	1.32	1.26	0.27
	PCP	0.36	1.86	1.12	1.17	0.41
	MH	0	1.92	1.21	1.19	0.42
C Average Betweenness						
	All	0	1904.83	14.41	120.08	322.56
	IM	3.94	66.31	35.23	31.15	22.12
ECOE	NEURO	15.96	1904.83	305.11	469.09	563.36
	PCP	0.03	48.83	6.31	14.07	17.23
	MH	0	37.75	4.35	9.62	11.75
	All	0	813.04	4.81	41.69	110.88
	IM	0	56.55	15.42	18.53	14.64
Non-ECOE	NEURO	6.31	813.04	164.81	224.60	202.29
	PCP	0	26.23	0.93	4.13	6.43
	MH	0	12.33	1.63	2.81	3.10

* Minimum average node degree with facilities that had neurologists. Some facilities did not have neurologists listed, and so the node degree for them was 0.
** All means only the four specialties listed here because data was not analyzed for the others.

lower in timely and accurate communication as well as understanding and respecting other professionals' roles compared to those inside ECOEs. Similarly, neurologists outside of ECOEs had a score indicating lower levels (<4) of accuracy in communication, the amount known about other people's roles, and the amount of blaming versus solving problems compared to those within ECOEs (Table 4).

3.3. Qualitative results

Table 3 present the themes, number of references (i.e., content coded to the node), sources (i.e., interview transcripts), and exemplar quotes from 80 participants' transcripts. Participants included 52 neurologists, 2 primary care providers, 14 nurses, 6 EEG techs, 4 AOs, and 2 other roles. Participants were employed at 66 VA medical centers, including 15 ECOEs and 25 of 51 spokes surveyed. All transcripts had at least one coded reference. The SNA themes and subthemes are presented along with exemplar quotes and consideration of strengths and weaknesses of SNA and RC for assessing these constructs.

4. Health provider social network

The VA, as with any healthcare system, has both formal and informal professional networks. Informal networks may be based on provider preference and proximity; for instance, primary care providers may prefer to consult a neurologist that they know or have had a positive experience with in the past. The ECOE is an example of a national formal network established to promote coordination of epilepsy care across VA facilities. In this system, smaller VA facilities are expected to refer to tertiary VA facilities that are within their region for advanced care such as epilepsy specialty care. The hub and spoke organizational structure of ECOEs provides an excellent example of designing a model to optimize coordination of care.

4.1. Networking for clinical care

In the interviews, we asked providers about their experience regarding the effectiveness of the ECOE network. Several providers noted that the ECOE network linked clinicians and staff beyond geographical constraints (regionally and nationally). Creating the network was seen as

Table 3
Social network analysis constructs, references, and exemplar quotes.

Social network analysis	Definition	References/sources 308/80	Exemplar quote
Health Provider Social Network	Social structures of individuals and groups. How structures, processes, and functions support interdisciplinary cooperation	94/42	We have comanagement with neurologists at other facilities and we have comanagement with the primary care at our facility. We have certainly talked locally about models of involving primary care more for these and other patients. – P79, Epileptologist, ECOE
Social Support/ Social Capital	How social support and social capital (particularly in the context of stressful or challenging situations) influences health services and healthcare delivery	13/13	We are trying to set up a team. You need a psychiatrist who specializes in this condition and a neurologist who specializes in this condition so that we do not undercut each other and we work together. The patient can play them off each other if you don't have a team approach. – P25, Neurologist, ECOE
Social Influence	How actors (other providers) influence healthcare behavior (e.g., diagnostic and treatment practices)	15/11	Another thing that has helped me a lot is the group of physicians from another region and the monthly teleconference we have to review cases. I feel like we have a set of colleagues who are experts in the field to whom I can go to and run cases by them—that is really helpful to me. – P56, Epileptologist, Spoke
Information Sharing/Transmission	How information is exchanged or transmitted across healthcare providers	80/46	What we have done is that we have actually established many interfacility consults. We are working in close collaboration with these referring neurologists and making sure that they are able to see our notes, our reports, and our recommendations on how to follow up with the patients. – P63, Nurse Practitioner, ECOE
Interorganizational relationships	How different agencies and organizations (as opposed to individuals) are connected and/or share resources	107/49	I think the fourth biggest accomplishment is reaching out to the community and participating more actively with the Epilepsy Foundation here in this state. We have made a very good connection. We had events combined where they come here to our veterans for our support group. – P75, Epileptologist, ECOE

Table 4
Quality measures: respondent ratings of coworkers (means).

Coworker	Timely communications	Accurate communication	Blaming or solving problems	Amount known about my role	Others respect my role	Others share my goals
Primary Care	3.5	3.8	4.0	3.2	3.6	3.5
General Neurologist	3.8	4.0	4.2	4.0	4.0	4.1
General Neuro Outside	3.5	3.5 ↓	3.9 ↓	3.3 ↓	3.7	3.8
Epileptologist	4.1	4.4	4.3	4.3	4.3	4.4
Epileptologist Outside	3.7 ↓	3.9 ↓	4.1	3.6 ↓	3.6 ↓	4.1
Nurse Practioner/PA	4.2	4.5	4.5	4.3	4.5	4.4
Psychologist	4.0	4.2	4.3	4.0	4.3	4.3
ER Physician	3.8	4.0	3.7	3.6	3.9	3.8
Pharmacist	3.7	4.1	4.1	3.8	4.0	4.0
Clinic Nurses	4.2	4.2	4.2	4.0	4.1	4.1
EEG Techs	4.2	4.3	4.1	4.2	4.3	4.3
Administrative Personnel	4.1	4.2	3.9	4.0	4.2	4.3
Neurosurgeon	4.3	4.3	4.4	4.2	4.4	4.6
Neuroradiologist	4.0	4.1	4.2	3.7	4.0	3.9

an important accomplishment by management and perceived by providers as critical for improving care.

> "I think networking is important. Being part of one big group that works together towards something is a lot more efficient than being by ourselves because we are sharing our experiences and resources." – P80, Neurologist, ECOE

The formal nature of the ECOE seemed to facilitate strong physician-to-physician connections directly related to patient care and coordination of care. Some epileptologists talked about forming deeper professional relationships with referring physicians by establishing direct relationships, sometimes comanaging patients.

> "When first started we didn't know the names of the neurologists who refer to us. We started tracking people who refer to us and developed that relationship. That took time." — P45, Epileptologist, ECOE

The ECOE specialists identified providers within their regions and established more personal relationships with referring providers and created new relationships with providers, particularly those in rural areas. Social network analysis measures should reflect any increase in referrals and shared patients while RC may reflect an increase in communication across providers because of increases in clinical care.

> *"Areas of the country where the pool of specialists are not as heavy have benefited from having gained access to specialists remotely. I think that has rolled over to the patient as well. A key example is tele-EEG and some of the tele services that have been implemented to allow access for our Veterans to the specialist."* — P68, Epileptologist, ECOE

4.2. Networking outside of clinical care

Relational coordination and SNA do not directly capture the degree of professional networking that occurred outside of clinical care. For instance, beyond direct patient care, the ECOE developed a number of programs and workgroups that promoted professional social networks that involved administrative, educational, and research collaborations. Some workgroups developed standard operating procedures, instructional manuals/videos, pocket guides for antiepileptic drug prescribing as well as providing encouragement and professional development.

> "Epilepsy monitoring units (EMU) as part of the regular neurology unit are pretty common. We needed to provide training to nurses who care for those patients to make sure it is as safe as possible. We've had a lot of collaboration from nurses which led to development of the EMU safety video and a standardized nursing competency checklist." — P71, Nurse Practitioner, ECOE

Research collaborations that did not exist before the establishment of the ECOE may have been promoted directly by the ECOE research workgroup as well as indirectly by data collected across facilities. However, these social networks between providers would not be captured in either the SNA or RC measure directly.

> "We have a coordinated network that gives us research opportunity." — P76, Epileptologist, ECOE

4.3. Provider social networks and SNA/RC

Health provider social networks increase efficiency, resource sharing, and knowledge transfer. Social network analysis may reflect increases in referrals and shared patients. Relational coordination may reflect increases in communication and quality of relationships between providers. Finally, while SNA may not reflect increased research collaboration, RC may indirectly be impacted by increased communication across facilities and neurologists who are working on research projects together because there are more regularly communicating with each other.

5. Social support/social capital

5.1. Creating social capital

Professional identity was seen as critical to the implementation of the ECOE. Several of the interviewees reported feeling connected to the ECOE network and a sense of support from their colleagues and that the network provided their service credibility.

> "The ECOE promoted advocacy for epilepsy. Veterans in the hospital know that this is a big thing, and the ECOE provides a stamp of approval for the care of epilepsy within our group." — P57, Nurse Practitioner, ECOE

Social support beyond physician support, such as social work, psychology, nursing, and administration for communicating to patients ensured program goals were achieved.

> "As a result of the center and having some time to organize, we have been able to bring in some additional care providers to help provide comprehensive care for patients, including an excellent social worker who is invaluable in helping us get the patients to the care

they need and take care of them in a more comprehensive fashion." — P40, Epileptologist, ECOE

Social support provided not only support for professional development but also intangible benefits and increased understanding of care coordination for patients with epilepsy. Social support seemed to be linked to professional engagement and increased patient-centered care.

"It is very beneficial when the technicians have an opportunity to sit and chat. We do not get to do it every time." — P3, EEG Technologist, Spoke

"It's an interdisciplinary clinic, and my role integrates psychology and mental health with epilepsy. I have the neurologist, the epileptologist, and the nurse practitioners there to help me understand the special needs of patients with epilepsy." — P61, Neuropsychologist, ECOE

5.2. Managing barriers to building social capital

Limited funding to coordinate outreach and provide patient education was cited as a barrier to developing social capital across providers. While most networking occurred through telephone or web-based conferences, face-to-face interactions were considered important for professional development and knowledge transfer.

"I think it is pretty frustrating when it comes to cutting out monies for travel and things that ECOEs are trying to do." — P33, Epileptologist, ECOE

5.3. Social support/social capital and SNA/RC

The sense of identity, being part of formal network facilitated collaboration, is not measured by either RC or SNA. Although neither RC nor SNA directly measure social support or social capital, they may be affected indirectly by variability in individual perceived social support and social capital.

6. Social influence

6.1. Bridging gaps between agents

Providers report that educational programs in particular influenced other providers as well as patients. Educational programs bought together specialists, generalists, patients, and external organizations nationwide.

"The other good thing that has come out of this has been education for providers in the area and patients about what to expect." — P16, Administrative Officer, ECOE

"It allowed me the opportunity to start to inculcate the staff with more accurate notions about the nature of the underlying problem of epilepsy and a more organized and systematic way of making the diagnosis and separating out the various different kinds of considerations in a clinical context." – P11, Neurologist, Spoke

Variability in the degree of social influence across networks is demonstrated when respondents, who are more socially connected to formal networks, report appreciation of expertise and support offered by other network members. Formal networks included workgroups where ECOE hub and spoke providers were tasked with solving specific problems such as advancing research or providing mental healthcare.

6.2. Managing barriers to social influence

Providers at spoke referral facilities felt more attuned to the ECOE than providers not affiliated with the ECOE, and some expressed desires for more opportunities to participate in the network. Clinicians and staff across facilities often cited barriers to participation that arose from scheduling conflicts between their clinical hours and educational opportunities. Several ECOE providers noted that the website served to enhance the ability of providers to connect to the centers.

6.3. Social influence and SNA/RC

The RC surveys may be useful for identifying barriers to social influence such as perceptions of infrequent or inaccurate communication, and SNA might be useful in identifying emerging networks of providers.

7. Information sharing/transfer

7.1. Using technology

Formal educational programs established by the ECOE including teleconsultation were perceived as useful for information sharing within the ECOE hub and spoke network. Educational materials were created both nationally and by a number of working groups as gaps in knowledge about coordinating epilepsy care became apparent. Many of these educational materials were originally produced for one facility but spread through the network to other ECOE hubs and spokes.

"We created videos and teaching guidelines for staff. Those are things done on a national level." — P71, Nurse Practitioner, ECOE

Furthermore, the centralized electronic health record was found to be critical in information sharing. The EHR templates were developed in several facilities for quality improvement and research purposes, for example. Providers could access data from other facilities and could provide complete documentation (e.g., imaging and reports) on a single, nationwide system accessible to the referring physician.

"Remote data is the best thing since sliced bread. The fact that we can look into charts in other states and see what is going on with the patients is the biggest help in being able to get information on patients. I cannot stress that enough." — P15, Nurse Practitioner, ECOE

7.2. Streamlining referrals

The referral process in the ECOE network was streamlined to ensure timely care for veterans with epilepsy. The new referral process improved the efficiency in patient–provider encounters. Moreover, the EHR permitted providers to virtually consult with specialists, sometimes sparring patients the need to travel for an appointment and reducing the number of hours spent at clinics. Progress notes in the EHR typically contain detailed information and explanations as well as recommendations for ongoing care.

"Our e-consult system seems to help with referrals. We have an e-consult template that the primary care or general neurologist completes. It requires them to order and get the EEG before they send the patient so that our time is spent more efficiently." — P71, Nurse Practitioner, ECOE

7.3. Information sharing/transfer and SNA/RC

Complex and/or tacit knowledge (knowledge that is difficult to explicate) is transmitted effectively through strong relationships, and RC

provides a direct measure for the means, quality and frequency of information sharing. However, SNA does not directly show how information is shared or the quality of communication between individuals.

8. Interorganizational relationships

Within a healthcare system, there are multiple levels of interorganizational relationships including the following: within or outside a facility or region; within or across disciplines; and with stakeholders within or outside the VA.

8.1. Facilitating relationships

Logistical processes such as electronic orders, electronic templates, and travel coverage facilitated collaborations across hospital facilities.

> "We have actually established many interfacility consults. Now we're starting to get busy. The patients are being referred to us. The word is getting out that we have the ECOE." — P63, Nurse Practitioner, ECOE

> "The ECOE have allowed for collaborations of specialists across the nation, not just the ones in the epilepsy center but other epileptologists in the VA and those who are caring for epilepsy. It has allowed for a network to collect information and to share information, creating a network of sharing that I think has rolled over and been a benefit to the patient." — P16, Administrative Officer, ECOE

The ECOE program also works with other patient-centered advocacy groups. These groups are viewed as essential for providing additional patient education and support. Some facilities have regularly scheduled classes/events and/or have an organizational member onsite. Many respondents found these organizations to be invaluable for providing current information to Veterans.

> "I usually refer them to the Epilepsy Foundation or Epilepsy.com. They are really helpful." — P27, Nurse Practitioner, Spoke

8.2. Managing barriers

The primary barrier to interorganizational coordination was related to contracting. We observed barriers to formalizing relationships with the Epilepsy Foundation for providing educational/support facilities. Sometimes bureaucratic barriers blocked or significantly delayed the launch of a telehealth clinic:

> "It was a huge challenge—you know how those things go. We had to get memorandums of understanding and have people sign off. And then sometimes that process would go so long it would go onto someone else's desk and they would raise roadblocks. By that time there would be change in clinic times at the remote site and we would have to reorganize. It took a long, long time. I am guessing nearly two years to get our first telehealth clinic happening." — P49, Epileptologist, ECOE

8.3. Interorganizational relationships and SNA/RC

The quality of interorganizational relationships is not effectively identified in administrative data, highlighting a limitation of SNA. Relational coordination data can be used to assess information sharing between networked organizations. Social network analysis may also prove inadequate for identifying other professional roles, such as nurses, that are important for coordinating clinical care.

9. Discussion

As neurologists increasingly engage in quality improvement programs and health services research, tools to effectively measure the coordination of neurological care will be needed. The primary advantage of SNA is that it clearly visualizes and maps coordination of care (Fig. 2). The visualizations can show relationships between disciplines (such as neurology, neurosurgery, primary care, and mental health); they can show changes in relationships over time to determine the impact of an intervention; and teams and/or facilities can be compared easily. Another advantage of SNA is that provider relationships can be easily quantified in an automated way through an EHR. The primary and distinct limitations of SNA include dependence on clinician encounters exclusively, so the role of administrators and nurses in facilitating coordination of care cannot be quantified or mapped. Furthermore, the most straight forward SNA metrics (node degree and node strength) may not always reflect how well information is exchanged or the quality of communication. The value of node degree may be inflated if a provider refers many patients to many providers while communicating poorly with the providers to whom he/she refers.

The primary and distinct advantage of RC is that it provides a detailed assessment of communication across all stakeholders of patient care (Table 4). The primary disadvantage is the effort and resources required to collect RC data from each care team.

This study attempted to compare and contrast social network data with RC data and qualitative interviews to explore and explain the advantages and disadvantages of SNA. Rather than speculate how SNA and RC measures capture social network constructs, our qualitative data provide insight into the experiences of providers within the network. The semi-structured, key informant interviews illustrate the many dimensions and factors that inform physician-to-physician social networks, communication, and information sharing. Since SNA connections are simply defined by number of shared patients, the factors that shape and inform provider connections (such as technology, training, communication) are not directly measured. Interviews demonstrate how SNA and RC are not able to capture the degree, and how informal collaborations such as through research, educational programs, and working on administrative committees enhance physician networks. Furthermore, connections with administrative and ancillary staff play a critical role in patient coordination and are not captured in the SNA metrics. The qualitative data describing provider and staff experiences also offer potential explanations of the variance in of SNA and RC scores across facilities. In so much as facilities vary with the degree of professional networking (within and outside the clinical setting), fostering professional identity and social capital, bridging communication gaps between providers, optimally using technology for information sharing, and leveraging interorganizational relationships, RC and SNA scores may vary accordingly. While SNA is limited in that they do not provide the mechanisms of how provider communication may occur, it remains valuable in offering a dynamic metric of connectivity that may be used for large healthcare systems.

9.1. Limitations

The limitations of our research reflect the limitations of the application of SNA and RC in the real world. For instance, the response rate for RC at individual sites was relatively low; RC is optimally conducted in-person at a site level with careful inclusion of all known roles across the network. However, the amount of resources needed to conduct in-person collection of date for RC is high. The small sample size is, at least partially, due to the setting of this project as well. Only approximately one administrator, two to three EEG technologists, and one nurse work at each facility; therefore, the range of RC scores is inherently limited. Although RC scores can range from 1 to 5, all RC scores had a narrower range of values, with no low scores, which in turn

impact the correlation. In general, most results scored higher than expected and may have skewed the results.

While we attempted to survey all epilepsy care providers in the VA system, our database, assembled from numerous national sources, was incomplete, and we were not able to identify all appropriate personnel. We made efforts to interview providers who referred to the ECOE but no comprehensive list of referring physicians was available. We did, however, attempt to recruit providers with established referral relationships and all those associated with various workgroups. Not every provider/staff member within the known network completed a survey. Furthermore, we did not survey or interview any interorganizational representatives. We did, however, interview ECOE personnel from all the sites as well as a significant number of spoke personnel, and conducted interviews to saturation. Additional interviews with spoke facilities may have revealed additional information about network formation and shed light on additional barriers to forming networks. Because of privacy issues, the RC survey did not collect data on the identity of site/role being rated by the respondent, and it was therefore not possible to directly link "within" and "outside" facilities at a granular level. Moreover, not every person who was also interviewed completed a survey, although there was considerable overlap. We included in our sample providers with high and low/no referral to the ECOEs in order to explore factors related to use of the ECOE for tertiary care and educational/telehealth resources and barriers to networking.

10. Conclusion

Social network analysis and RC are complimentary measures of care coordination. The advantage of using SNA, specifically shared patients as the measure of connectivity, is that it is an objective measure that can be assessed over time without relying on the provider to complete and return a survey. Theoretically, if the data are available, the entire provider network may be mapped and tracked. Healthcare administrators can track the dynamics of their network of providers as well as interventions on the network almost in real time. Interventions that may theoretically improve coordination of care among networked providers have been described [18], but few studies have actually experimentally tested the impact of network interventions. In contrast, RC provides stakeholders with detailed information on individual-level relationships within each team. While RC is a more subjective study of the relationships between network provider, it provides a more granular measure of team function. The study demonstrates the value of coordination of care measure, and we hope to encourage the use of these tools in neurology-related health service research as they may be used to identify gaps in communication and isolation of providers within facility. Use of these measures may ultimately benefit quality of care and outcomes for patients with epilepsy.

Ethical approval

Ethics approval and consent to participate. Ethical approval was granted by the VA Connecticut Healthcare System Institutional Review Board and consent was waived.

Consent for publication

Not applicable.

Availability of data and material

The datasets generated and analyzed during the current study are not publicly available due U.S. federal government regulation. Veteran health data are available in the VA Corporate Data Warehouse and may only be released by the Veteran Healthcare Administration.

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Authors' contributions

HA, HL, KM, BF, and MJP contributed to the design of study. HL, KM, KC, and MJP contributed to data collection, HA, HL, KM, BF, KC, and MJP contributed to the quantitative data analysis while HA, HL, KM, and MJP contributed to the qualitative analysis; HA, HL, KM, BF, and MJP contributed to interpretation of the results and editing the manuscript.

Declaration of Competing Interest

The authors declare that they have no competing interests.

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Elise Boucher performed qualitative analyses. Barbara Elizondo designed the RC survey and analyzed survey data.

References

[1] Institute of Medicine. Crossing the quality chasm: a new health system for the 21st century. National Academy Press; 2001.
[2] Kirschner N, Greenlee M. American College of Physicians. The patient-centered medical home neighbor: the interface of the patient-centered medical home with specialty/subspecialty practices. Position paper. Philadelphia: Amer College of Phys; 2010 [In; 2010].
[3] Newman ME. The structure and function of complex networks. SIAM Rev 2003;45:167–256.
[4] Barnett ML, Landon BE, O'Malley AJ, Keating NL, Christakis NA. Mapping physician networks with self-reported and administrative data. Health Serv Res 2011;46:1592–609.
[5] Gittell JH. Relational coordination: coordinating work through relationships of shared goals, shared knowledge and mutual respect. Relational perspectives in organizational studies: a research companion; 2006; 74–94.
[6] Gittell JH. High performance healthcare: using the power of relationships to achieve quality, efficiency and resilience; 2009.
[7] Barnett ML, Christakis NA, O'Malley J, Onnela JP, Keating NL, Landon BE. Physician patient-sharing networks and the cost and intensity of care in US hospitals. Med Care 2012;50:152–60.
[8] Landon BE, Keating NL, Barnett ML, Onnela JP, Paul S, O'Malley AJ, et al. Variation in patient-sharing networks of physicians across the United States. JAMA 2012;308:265–73.
[9] Gittell JH. High performance healthcare: using the power of relationships to achieve quality, efficiency and resilience. New York: McGraw Hill; 2009.
[10] Gittell JH, Fairfield KM, Bierbaum B, Head W, Jackson R, Kelly M, et al. Impact of relational coordination on quality of care, postoperative pain and functioning, and length of stay: a nine-hospital study of surgical patients. Med Care 2000;38:807–19.
[11] Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. Adm Policy Ment Health Ment Health Serv Res 2015;42:533–44.
[12] Pugh MJ, Leykum LK, Lanham HJ, Finley EP, Noël PH, McMillan KK, et al. Implementation of the epilepsy center of excellence to improve access to and quality of care–protocol for a mixed methods study. Implement Sci 2014;9:44.
[13] Dillman DA. Mail and internet surveys: The tailored design method—2007 update with new internet, visual, and mixed-mode guide. John Wiley & Sons; 2011.
[14] Borgatti SP, Everett MG, Johnson JC. Analyzing social networks. . 2nd ed.Los Angeles: SAGE; 2018.
[15] Bastian M, Heymann S, Jacomy M. Gephi: an open source software for exploring and manipulating networks. International Association for the Advancement of Artificial Intelligence (AAAI) conference on weblogs and social media. San Jose, California, USA: AAAI Publications; 2009.
[16] Glaser BG, Strauss AL. The discovery of grounded theory; strategies for qualitative research. Chicago: Aldine Pub. Co; 1967.
[17] Hsieh HF, Shannon SE. Three approaches to qualitative content analysis. Qual Health Res 2005;15:1277–88.
[18] Valente TW. Network interventions. Science 2012;337:49–53.